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PATTERN SCORING OF A SHORT-FORM TEST FOR PREDICTING SUCCESS IN A NAVY 'A' SCHOOL

Kenneth Paul Weinberg

Naval Postgraduate School
Monterey, California

March 1973

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THESIS

Pattern Scoring of a Short-Form Test for Predicting Success in a Navy "A" School

by

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I. INTRODUCTION

The Navy has been very much interested in recent years in the possibility of using short-form tests to reduce testing time while maintaining or even increasing test reliability and validity.

The advantages of a short-form test are manifold. With a short but reliable and valid test the Navy could save thousands of dollars in training costs by weeding out, before training even began, those individuals who would probably not succeed. The administration of the test could be done at a training command, e.g., Naval Training Center, San Diego, Bainbridge, etc., or even by a recruiter. For example, if an individual desires to be a radioman and talks to a recruiter about joining the Navy only if accepted for radioman training, it would be advantageous for both the service and that individual if a brief test of possibly five to seven minutes' duration could be administered, graded and evaluated on the spot against the individual's desires for such a Navy career. With this brief test both the Navy and the potential recruit would know, in a relatively short period of time, whether the man would succeed in radioman training.

II. BACKGROUND

Moonan (Ref. 1) pioneered this type of work for the Navy by constructing a computer program having the capability of identifying combinations of test items that have maximal validity. This program, entitled SEQUIN (an acronym for Sequential Item Nominator) first selects an item that has highest validity with the criterion. The program then continues to select another item which, when combined with the first, produces a two-item test with a higher validity than any other two-item test that includes the first item. This process continues until the required number of items is selected and the maximum validity for this number of items is obtained. The advantage of such a program is that a fairly long test, such as the General Classification Test (GCT), might be shortened without sacrificing validity while test time might be significantly reduced.

SEQUIN has shown, repeatedly, that a short-form test is at least as predictive of final school grade as its long-form counterpart (Ref. 2). Swanson and Rimland (Ref. 3) have found that a short form of the GCT, e.g. one-half to one-third of the original length, is even more predictive of recruit final achievement (RFAT) than the complete form.

III. THE PROBLEM

This study attempts to increase further the predictive validity of an already brief test. The method, developed by Dr. R. A. Weitzman of the Naval Postgraduate School, Monterey, California, is to weight item responses so as to maximize the correlation with the criterion.

On an n-item test where each question is graded to be either correct or incorrect, there are 2^n different possible patterns of correct and incorrect responses. Thus, for example, on a five-item test there are 32 possible pattern scores as opposed to six possible scores if just the number of correct responses were tallied.

For example, suppose a three question test is given to a group of recruits in an attempt to predict their success in a Navy training school. There are eight (2^3) combinations of patterns running from 000 to 111 (where zeros are incorrect responses and ones are correct). A subject having a pattern of 101 has the same number correct as another subject with the pattern 110, that is, two out of three. However, the first individual's score might be more predictive of success in a particular training school than the second subject's binary pattern.

This study will focus on four different tests or test scores, defined as follows:

1. Predictor - the predictor is a long-form test used for predicting success in a Navy training school. In this study, the predictor is the Electronics Technician Selection Test or the General Classification Test. Scores on the predictor are determined by counting the items answered correctly.

2. Criterion - the final school grade in the Basic Electronics and Electricity School.

3. Total Correct - the total number of correct responses out of the seven questions selected by SEQUIN analysis for this study.

4. Pattern Score - a special score assigned to each pattern of responses on the same seven items used to compute total correct. (A precise definition of pattern scores will be given in Section VE.)

Thus, the purpose of this study was to:

1. Gather large pools of data from a Navy training school,

2. Extract several suitable questions from the General Classification Test (GCT) and the Electronic Technician Selection Test (ETST),

3. Write a computer program that :

a. constructs all possible patterns of ones and zeros for the number of extracted questions

b. calculates pattern scores for each individual pattern

c. assigns pattern scores to subjects

d. correlates the pattern scores of the subjects with their final school grades

e. correlates the standard predictor test scores (either GCT or ETST) with final school grades

f. correlates total correct, with final school grades

g. correlates pattern score with total correct

h. calculates a multiple correlation coefficient between a combination of pattern scores and total correct and final school grades

i. calculates test statistics for the correlations

j. calculates regression weights for predicting final school grades from total-correct scores

k. creates a frequency distribution showing number of subjects with each pattern score

l. outputs all information in an easy-to-read form for use in future studies

4. Determine those patterns indicative of success for a particular training school,

5. Test pattern-score predictions by suitable cross-validation.

IV. DATA

All data used in this research were obtained from Mr. Leonard Swanson of the Naval Personnel and Training Research Laboratory, San Diego, California, and were stored on nine-track magnetic tape (Ref. 4). The data consisted of the individual records of approximately 2400 trainees who started, but not necessarily finished, the Navy Basic Electronics and Electricity School in San Diego. Each trainee's record consisted of the equivalent of six-computer card records listing such information as:

1. Responses to items on the GCT, ETST, and Arithmetic Aptitude Test (ARI)
2. Scores on the GCT, ARI, and ETST
3. Navy service number
4. Enlisted rating
5. Final school grade in Basic Electronics and Electricity School

Tests used as predictors included the GCT and ETST. The GCT consists of 60 verbal analogies and 40 sentence-completion items with a 35-minute time limit. The ETST consists of three separately timed sections: math with 20 items and a 25-minute time limit; science with 20 items and a 15-minute time limit; and electricity and radio with 30 items and a 20-minute time limit (Ref. 5).

Two sets of questions were provided by Mr. Swanson along with their answer keys. The first set of questions, consisting of seven GCT items, and the second set, consisting of seven ETST items, were selected using the SEQUIN program. The p-values, question types and item validities are shown in Appendixes A and B.

The criterion consisted of final school grades in the Basic Electronics and Electricity School.

A. DATA PREPARATION

Two programs were written to extract and put into usable forms all pertinent data for the study. (A glossary of terms used in all programs is contained in Appendix L.) The first program checked for completeness of an individual's record, i.e., the presence of six computer-card images, and rejected those subjects whose files were deficient. Unfortunately several records contained special characters, e.g., dashes, asterisks, etc., instead of integers. Therefore, the first data preparation program converted any of these special characters to zeros. Thus, a response other than an integer from one to five was changed to a zero and counted as an incorrect response. If a needed score such as the GCT, ETST or final school grade was blank or contained some non-numerical mark, the record for that individual was rejected as being incomplete. (It is possible that some of those incomplete records resulted from subjects not finishing the school, i.e., being required to leave the service because of physical,

emotional, or academic problems.) The output from this program was written on tape or data cell and on paper.

Appendix C is the flowchart of this first program. Appendix D is the program listing.

Although a subject's record consisted of six computer-card records, most information was superfluous. Of the six cards, data from three, at most, were considered. Using the answer key supplied by Mr. Swanson, the second program graded, on different occasions those E TST or GCT questions under consideration. Specifically, it assigned a value of one to a correct response and a value of zero to an incorrect response. By assigning ones and zeros to the responses, the binary pattern was formed. The program also read the criterion score and the predictor score.

The output from this second program consisted of:

1. binary pattern
2. criterion score
3. predictor score
4. an in-house identification number
5. the subject's service number

Appendix E is the flowchart for this second program. Appendix F is the program listing.

V. THE MODEL

The main program is divided into several distinct sections: reading of data, determination of a joint frequency distribution, computation of pattern scores, assignment of pattern scores to subjects, computation of correlation coefficients (r's), computation of test statistics for r differences, construction of response patterns, ordering of response patterns according to the scores computed for them, calculation of a multiple correlation coefficient, calculation of the correlation coefficient between pattern scores and total correct construction of a frequency distribution showing the number of people with each pattern score, and output (printed and punched).

A complete listing of the program is presented in Appendix G.

A. DOUBLE PRECISION REQUIREMENT

Because of the large sample sizes and the relatively large magnitude of several parameters, it was necessary to use double precision floating point numbers.

B. THE DATA CARD

The data card initializes four variables that are frequently used in counting loops (DO loops). The variables, N1, N2, N3, and N4, represent, respectively, the number of people in the sample, number

of elements in a pattern, the range of criterion scores, and the number of possible binary combinations using N2 items (2^{N2}).

C. READING THE DATA

Data is read in only a prescribed format. For this program, the individual's data record card is set up as shown in Table I.

There are two read statements. One read statement carries out the reading of data that is to be used in the computations of the program. The other read statement reads a dummy variable, "IDUM." By placing the read statement involving IDUM before or following the main read statement (involving binary pattern, criterion, predictor, etc.), control over alternate selections of data can be attained. For example, if odd numbered data were only to be considered, the read statement involving IDUM would follow the main read statement thus acting as a dummy procedure to control data input. Note that all input data is in FORTRAN " I format."

The variable "J" is used as the DO LOOP counter involving personnel with only one exception. That exception is in the determination of the joint frequency distribution. An "I" DO LOOP is used for all other counting operations.

At this point, the total correct out of the extracted questions is calculated. The "E" array stores this information. This array is used in the calculation of the sum of total correct for all subjects and the sum of the squares of total correct for all subjects. This information is later used in the computation of correlation coefficients

TABLE I

RECORD DATA CARD SETUP FOR
VALIDATION AND CROSS-VALIDATION PROGRAMS

Column Number	Item	Program Symbol
1-7	Subject's binary pattern	P(I, J)
8, 9	Criterion Score	C(J)
10, 11	Predictor (Score on ETST)	A(J)
12-15	In-house ident. number	D(J)

and the mean and standard deviation for use in the calculation of a test-retest correlation coefficient.

D. THE JOINT FREQUENCY DISTRIBUTION

A joint frequency distribution is constructed using decimal equivalents of the 2^{N2} binary patterns and the range of criterion scores. The rows of the matrix (denoted by matrix variable F) represent the decimal equivalents of the binary patterns, and in this case there are 128 (2^7) binary patterns (the reason for using seven questions is explained in the METHODS section). However, the lowest binary pattern score (0000000) is also equal to the decimal value zero. Therefore, a value of one is added to all decimal equivalents. In this way the first row is row one, not zero, and the last row is row 128.

The column numbers correspond to successive criterion scores. Column one of the matrix corresponds to the subjects' lowest criterion score. In this case, the lowest criterion score was 30 and the higest was 99. The matrix is represented in Figure 1.

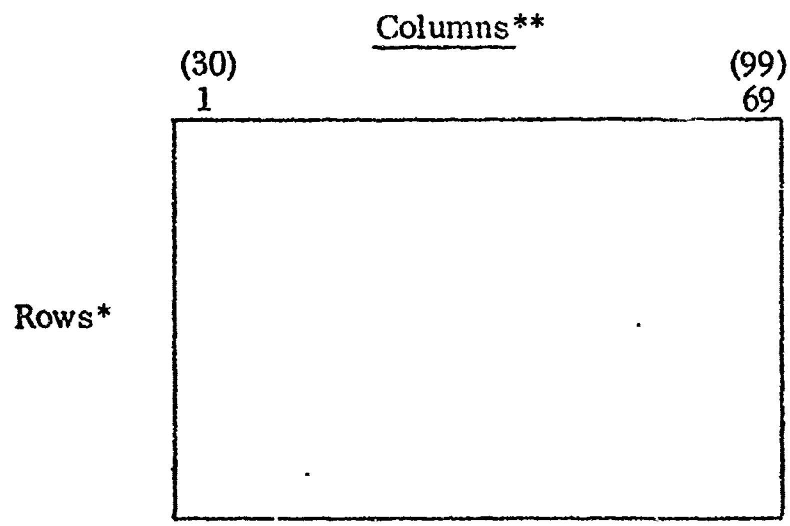
The "B" array is used to store the decimal equivalent of an individual's binary pattern.

E. COMPUTATION OF PATTERN SCORES

The pattern score for a pattern is the average score of subjects who have the pattern and is calculated from the F matrix by tallying the number of subjects having the pattern and each criterion score.

Figure 1

CONSTRUCTION OF A MATRIX DESCRIBING THE JOINT FREQUENCY DISTRIBUTION



*Row numbers are decimal equivalents of binary patterns plus one.

**Column numbers are criterion scores plus one minus the lowest criterion score. Numbers in parentheses are actual criterion scores.

This number is multiplied by the criterion score and summed, and the sum, S1, is divided by the total number of subjects having the pattern, S2.

If any of the 128 patterns is not used, because no one has the pattern, both S1 and S2 are set equal to zero, and an arbitrary score of -1 is assigned to the pattern.

Immediately following the computation of all pattern scores, the scores are outputted on punched cards. The pattern scores obtained in this study are presented in Appendix H.

F. ASSIGNMENT OF PATTERN SCORE TO SUBJECTS

A subject's decimal equivalent to his binary pattern is determined, and he is assigned the pattern score for that decimal equivalent (the row index corresponding to the pattern in the F matrix).

G. COMPUTATION OF CORRELATIONS

Correlation coefficients are then calculated between the criterion and the predictor (GCT or ETST) and between the criterion and the assigned pattern scores.

The sums of criterion scores (C1), pattern scores (X1), and predictor scores (A1) are determined along with the corresponding sums of squares (C2, X2, A2). The sum of the products of the criterion and predictor scores (V), as well as the criterion and pattern scores (W), is also determined. The correlation coefficients for

pattern vs. criterion (R2) and predictor vs. criterion (R1) are then calculated. The Z test statistic for the difference between these r's is also calculated.

Three other correlation coefficients are computed later in the program: a multiple correlation coefficient (see I below), the correlation coefficient between total-correct and pattern scores, and a test-retest correlation coefficient used as an estimate of the reliability of total correct scores on the predictor.

H. CONSTRUCTION OF RESPONSE PATTERNS

Since there are 128 (2^7) different patterns of responses ranging from 0000000 to 1111111, the computer is assigned the otherwise tedious and difficult job of constructing and outputting these patterns. A difficulty encountered is that leading zeros of various binary patterns, although stored without incident in the machine, are lost upon printing. Because of this, all zeros in the binary patterns are converted to twos. This fact is noted on the printed output (Appendix H).

I. MULTIPLE CORRELATION COEFFICIENT

The multiple ocrrelation coefficient indicates the strength of relationship between one variable and a linear combination of two or more others that produces the strongest relationship. Since different predictor variables are sometimes intercorrelated and so duplicate one another, the multiple correlation coefficient depends on the

intercorrelation of different predictor variables as well as on the correlation of each with the criterion variable (Ref. 6).

Specifically, the multiple correlation between criterion scores and a combination of pattern scores and total-correct scores is computed.

Since the coefficient of multiple correlation considers the inter-relationship between the predictor variables, it should have, theoretically, a greater value than the correlation between either predictor and final school grades alone.

The significance of the multiple r is next computed using an F statistic where F is the ratio of the variance of the residuals on the criterion before considering the multiple correlation coefficient and the variance of the residuals after consideration.

J. COMPUTATION OF REGRESSION WEIGHTS

Since there is a possibility that some binary patterns will not be used (i.e., there may be some binary patterns no one has because the sample size is small in relation to the number of binary combinations), it is conceivable that an individual in the cross-validation group might have a pattern that no one in the validation group has. Correspondingly, regression weights are computed from the relation between total-correct and criterion scores in the validation group that are to be used as input in the cross-validation study to determine scores for individuals having pattern scores equal to -1.

K. OUTPUTS I AND II

The pattern responses are then sorted according to pattern score from the lowest (-1) to the highest (73.66) and, in conjunction with the pattern score and total correct of that binary pattern, are printed out in tabular form. The table and results thus obtained are shown in Appendix H as Output I.

Next, tables are prepared listing the subject's in-house identification, his predictor score, his final school grade (criterion score), the pattern score associated with his binary pattern, and, finally, the total correct scored out of the seven questions. A sample showing the first 50 subjects is presented in Appendix I as Output II.

L. ADDITIONAL OUTPUT

All correlations and test statistics computed during the execution of the program are also printed. These results are presented and discussed in the RESULTS section.

VI. CROSS-VALIDATION

Cross-validation is a method used to estimate the magnitude of sampling variation. In cross-validation, results are obtained from a second sample of people for comparison with the results of an initial sample. If the results obtained from the second sample confirm the results of the first the results are said to hold up under cross-validation.

In addition to the validation or main program, described in the preceding section, this study makes use of a cross-validation program, which is essentially a portion of the main program. It differs in that pattern score and regression weights derived from the previous program are read in with new subjects' personal data and that patterns are not constructed, pattern scores are not calculated, and there is no need for a joint frequency distribution. The program listing for the cross-validation is presented in Appendix J.

As can be seen from Appendix H, there are fourteen binary patterns that were not used by the validation group in the ETST study. Therefore, the cross-validation program has to determine if a subject has a pattern that was not used in the validation program and, if he has, it must assign him a score using the regression weights determined from the validation group and his total-correct score.

A. ASSIGNMENT OF PATTERN SCORES

Various other methods of assigning pattern scores to patterns that no individual in the validation group has were attempted. These methods included: using the average pattern score derived from the main program, weighting more heavily those patterns appearing more frequently than those appearing less frequently, ignoring a subject in the cross-validation who had a pattern no one had in the validation group (with adjustment of corresponding variables, e. g., sample size), and finally using the regression weights.

With only one exception, that of using the regression weights, all methods of attack failed. All pattern-score validities were significantly lowered in all the other cases. (The reason for the abrupt drop in pattern-score correlation coefficients in the cross-validation is discussed in the RESULTS section.)

Using the regression weights, however, pattern score validities maintained a maximum. Scores were obtained by adding the product of total correct and the slope regression weight to the regressed mean.

Inputs for the cross-validation consisted of the same information as noted in the main program plus the regression weights and the pattern scores from the main program.

The tabular results for the first fifty subjects (even numbers only) is presented in Appendix K as Output III.

VII. METHOD

The validation and cross-validation programs were first used on GCT data. Not only was the GCT data analyzed, but it also served, at the beginning of the research effort, as a test platform for debugging the validation and cross-validation computer programs. The study concentrated on the ETST data, however.

A. PRELIMINARY STUDIES

GCT data were used in preliminary studies. Use of GCT data as a predictor, as originally planned, was unsatisfactory because the GCT was not designed as a predictor of success in a training school and, of the seven questions considered in the study, approximately one-third of the sample subjects had all correct, which is hardly an indication of predictive validity.

The first step in the study was the determination of the sample size to be used in the validation and cross-valididation programs. Since the total number of possible combinations of ones and zeros was 128 (2^7), it was decided that an appropriate sample size in the main program would be 2,000. This would result in the theoretical utilization of 15-16 subjects per binary pattern:

$$\frac{2,000 \text{ subjects}}{128 \text{ patterns}} = 15.7$$

The remaining subjects in the sample (379) would then be used in cross-validation studies.

Table II summarizes the results of this first effort. As can be seen from these results, the greatest validity for the validation (main) group was obtained from the predictor vs. criterion scores ($r = 0.51$). However, the relationship between the pattern and criterion scores was only 0.44. Although lower than the predictor validity coefficient, it was still better than the r for total correct (0.37). The high absolute values of the test statistics indicate that all the differences were significant.

The cross validation tells essentially the same story. The validities for the pattern and total correct were very nearly the same as in the validation program. However, the validity for the patterns fell short of its counterpart in the validation program ($r_{xval} = .34$ vs. $r_{val} = .44$). This phenomenon resulted from the weighting of item responses which maximized the correlation with the criterion, i.e., minimized the error of prediction, thereby capitalizing on chance in the validation group. The fact that chance played an important role in the validation program was further illustrated by one subject who had a binary pattern with four ones, i.e., four out of seven correct, but who also had the highest of all pattern scores.

Another explanation for the substantial reduction in pattern vs. criterion validities is that the mean pattern score was used for

TABLE II

CORRELATION COEFFICIENTS AND TEST STATISTICS DERIVED FROM THE GENERAL CLASSIFICATION TEST

	Main	Cross Validation
r(pattern)	0.44	0.34
r(predictor)	0.51	0.52
Z	-2.72	-3.11
r(total ones)	0.37	0.36
Z	2.74	-.27

NOTE: 1. The first Z is for the difference between the pattern-criterion and the predictor-criterion correlations. The second Z is for the difference between pattern-criterion and total correct-criterion correlations.

2. The sample size in the main study was 2,000 subjects while the sample size in the cross-validation study was 379 subjects.

individuals in the cross-validation group who had patterns no one had in the validation group.

B. ASSIGNMENT OF PATTERN SCORES

Because of the discrepancies in pattern-score validities for both the validation and cross-validation programs, the problem of assigning a valid pattern score to an individual who, in the cross-validation process, had a pattern no one had in the main validation arose. Therefore, the several approaches mentioned earlier were formulated and attempted.

1. The First Solution

The first of these proposed solutions involved the use of weights proportional to the number of subjects having a pattern. The weights were to be calculated, along with the pattern scores, in the main program and outputted on punched cards. The theory behind this solution was that if a binary pattern appeared very frequently it should have been counted more heavily in the cross-validation than those patterns appearing less frequently. Once again, considering the subject who had the highest pattern score with only four correct, it would appear logical that that person was not typical and should not have been counted equally as others. That is, would it have been valid to give his score the same weight as a score that was 25 per cent more prevalent? If both scores receive equal weight, distortion of the validities must certainly occur. Unfortunately, a suitable method of computing and applying such weights was not found.

2. The Second Solution

The second solution was to reduce the number of questions used in the study from seven to six. With only six questions the number of binary combinations would have been significantly reduced (from 128 to 64) resulting in the utilization of more binary patterns. It was hoped, in fact, that all binary patterns would have been used. Thus, when going into the cross-validation phase all patterns would have had pattern scores and the need for generating pattern-score substitutes in the cross-validation could have been eliminated. However, even with consideration of only six questions (64 combinations of ones and zeros), eight binary patterns were not used. Furthermore, the magnitudes of the correlation coefficients decreased markedly. Therefore, this approach was eliminated.

3. The Third Solution

The third solution called for the elimination of those subjects in the cross-validation who had a binary pattern no one had in the validation study. The theory behind this solution was, in essence, to eliminate the problem by pretending it wasn't there. This solution was not suitable for apparent reasons. For a test to be valid in a real environment, vis a vis a laboratory environment, it must consider all contingencies.

4. The Final Solution

It was finally decided to calculate regression weights and use these in assigning pattern scores to subjects in the cross-validation who had patterns no one had in the main program.

C. READ IN OF ALTERNATE DATA

The possibility of sample bias was also considered, e.g., predictor or criterion scores of the entire sample could have been placed in order of increasing or decreasing magnitude. Therefore, it was decided to split the sample in half; the first half to be used in the validation program and the second half in the cross-validation program. The main or validation program was then designed to read the records of every alternate subject, e.g., every odd-numbered subject, and make appropriate calculations from those data. The cross-validation also read every alternate but complementary record. Thus, for example, if the main program read every odd record, the cross-validation program correspondingly read every even record. Unfortunately, however, splitting the sample this way resulted in a drop in the number of subjects per binary pattern from fifteen to approximately nine.

D. THE ETST STUDY

After solving the problem of assigning pattern scores to subjects in the cross-validation study, the research focused on utilization of the ETST as the predictor.

Data preparation followed the same procedures as those noted in the data-preparation section of this thesis.

In addition to the tables and correlation coefficients computed in the validation and cross-validation processes, the programs also outputted the sum of total correct and the sum of the squares of

total correct for all subjects. This was used in the computation of the mean and variance for total correct (total ones). The reason for these calculations was to determine the test-retest correlation coefficient.

1. Test-Retest Reliability Coefficient

The test-retest reliability coefficient, as described by Weitzman (Ref. 7), is an estimate of the correlation between identical versions of a test taken by the same persons in independent trials. For a test with n-items and a-alternatives, this estimate is:

$$r_{tt} = 1 - \frac{n-M}{aS^2} \qquad (1)$$

where M and S are the mean and standard deviation, respectively.

This estimate of the test-retest reliability coefficient can be used in the determination of the correction for attenuation.

2. Correction for Attenuation

Because correlation results are obtained from fallible measurements, errors tend to reduce or attenuate the correlation between traits. Using the formula for correction for attenuation, it is possible to estimate what the correlation would be if perfect, errorless measurements were available (Ref. 8). Correlation coefficients that are corrected for attenuation cannot be used in prediction equations but can be used when analyzing relationships to make allowances for random errors of measurement.

Using the test-retest correlation coefficient computed for the predictor, it is possible to calculate the validity of the predictor

corrected for attenuation. The value obtained from the following formula is the theoretical correlation coefficient if the predictor were error-free:

$$r_{\infty C} = \frac{r_{PC}}{\sqrt{r_{pp}}} \tag{2}$$

The correlation coefficient r_{PC} is the measured validity between the predictor and criterion, and r_{pp} is the test-retest reliability described in the previous section. A comparison between the validity coefficient (r_{PC}) and the validity coefficient corrected for attenuation ($r_{\infty \cdot C}$) was used as an indication of how close this study came to the theoretical limit of validity for the predictor. Specifically, r_{PC} (total correct vs. final school grade) was compared to the corresponding correlation coefficient corrected for attenuation.

VIII. RESULTS

A. DETERMINATION OF LINEARITY

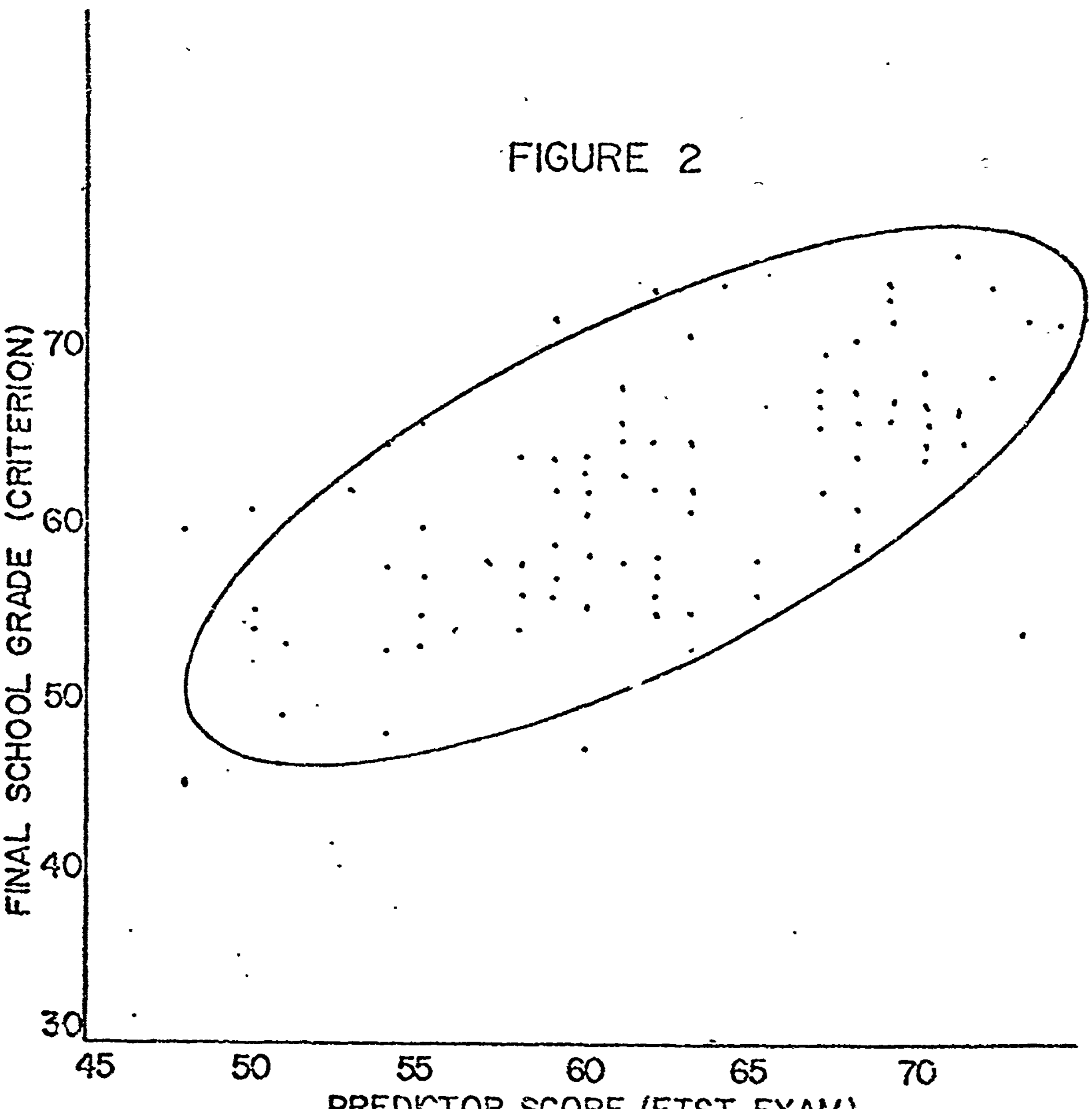
A product-moment correlation coefficient is good only if a linear relationship exists between the variables that are being correlated. Figures 2 and 3 are scatter diagrams which were used to determine if a linear relationship existed between total correct out of seven and final school grade and the full ETST score and the final school grade. Note that almost all the points can be enclosed in an oval which goes from the lower left to the upper right, therefore indicating linearity (Ref. 9).

B. CORRELATION COEFFICIENTS AND TEST STATISTICS

Table III lists the values for all test statistics and correlation coefficients.

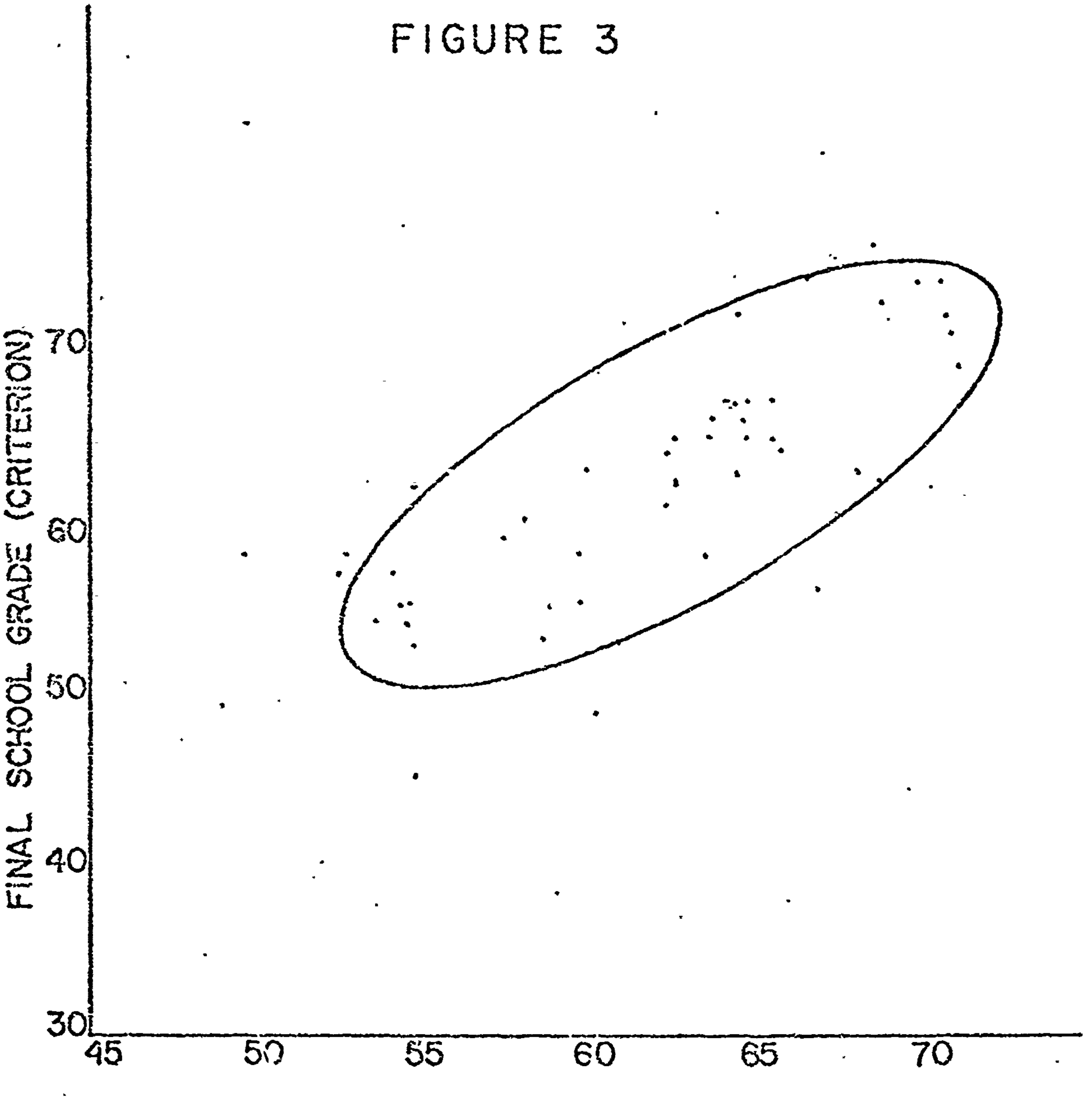
As can be seen from that table, the value of $r_{\text{pattern score}}$ decreases from 0.76 in the validation program to 0.72 in the cross-validation program, the reduction due to maximization of chance in the main program. The computation of the multiple correlation coefficient was desired to see if pattern scores add to the predictive ability of total-correct scores. The multiple correlation coefficient did not increase the value of $r_{\text{total correct}}$ thus indicating no additional predictive ability. The

FIGURE 2



SCATTER PLOT

FIGURE 3



SCATTER PLOT

TABLE III

CORRELATION COEFFICIENTS AND TEST STATISTICS DERIVED FROM THE ELECTRONICS TECHNICIAN SELECTION TEST

	Main	Cross-Validation
r(pattern score)	0.76	0.72
r(predictor)	0.61	0.60
Z	7.13	4.93
r(total correct)	0.72	0.73
Z	2.26	-.54
r(pattern score/ total correct)	0.95	0.95
r(multiple)	0.76	0.73
F	176.36	15.38
r(test-retest)		0.73
Correction for Attenuation		0.85

NOTE: 1. The first Z is for the difference between the pattern-criterion and the predictor-criterion correlations. The second Z is for the difference between pattern-criterion and total correct-criterion correlations.

2. The sample sizes in both the main and cross-validation studies was 1,182 subjects.

large value of F indicates that the total-correct scores contributed significantly to the predictive ability of the pattern scores, however.

The high value of the correlation coefficient between pattern scores and total-correct scores indicated that the seven items used in the study constituted a very valid test and that the total correct could be used as a predictor that is as good as the pattern scores for these items.

The correction for attenuation revealed that the highest validity theoretically obtainable by improving the reliability of the seven-item predictor was 0.85, The value actually obtained, 0.73, was equal to the test-retest reliability of the test. Since it is not reasonable to expect that a test will correlate more highly with another test than it does with itself, it is no wonder that the pattern scores did not correlate better with the criterion than the total-correct did.

IX. CONCLUSION

The two FORTRAN computer programs developed in this study successfully determined and correlated pattern scores with the criterion. However, the questions extracted from the ETST were so highly valid that they could have been used alone, i.e., without pattern scoring, as predictors of success in the Basic Electronics and Electricity School.

It would be interesting to continue this study using biographical information, not ordinarily quantifiable, instead of extracts from current examinations. Biographical questions carefully constructed and easily verifiable could be used in predicting behavior, and pattern scoring is a method that can be used to quantify responses to these questions. Responses quantified by pattern scoring, in fact, will show the highest possible correlations with predicted behavior.

APPENDIX A

The Seven Best GCT Items Selected by SEQUIN

(1) Form 7 Item Number	(2) Item Type	(3) Recruit p Value	(4) Median School p Value	(5) Median School Validity
13	A	.77	.88	.22
19	SC	.60	.78	.20
31	A	.75	.85	.20
55	A	.41	.49	.24
62	SC	.60	.69	.26
67	SC	.80	.87	.26
94	SC	.55	.78	.30

NOTE: 1. Values in Columns (4) and (5) are based on item data only for schools in which that item was selected in Program SEQUIN.

2. A = analogies; SC = sentence completion item.

APPENDIX B

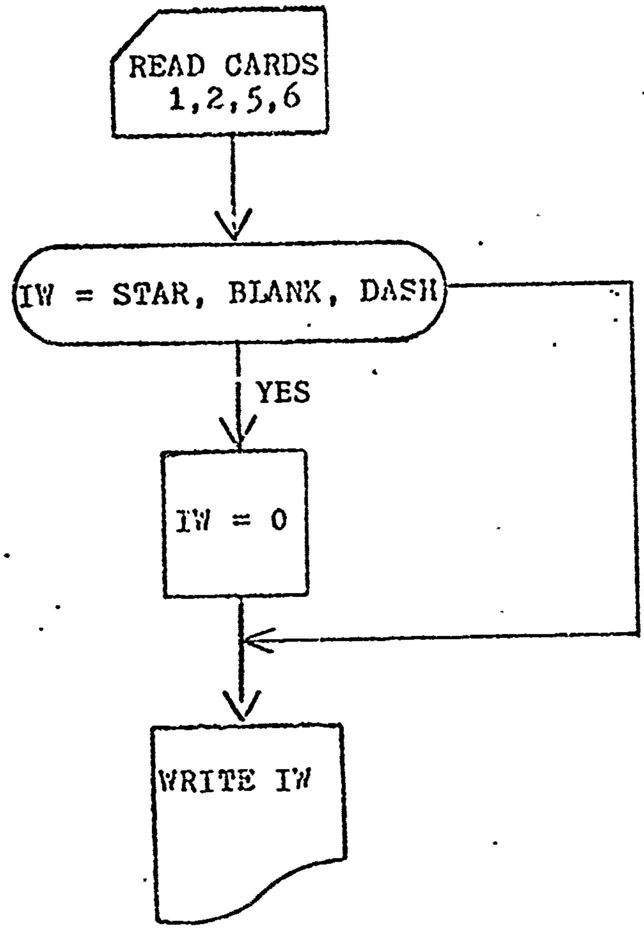
The Seven Best ETST Items Selected by SEQUIN

Question Number	Item Type*	Recruit P-Value	Median School P-Value	Median School Validity
3	M	.57	.71	.34
11	M	.38	.58	.44
13	M	.58	.69	.32
22	S	.57	.77	.34
40	S	.21	.37	.40
41	E	.31	.39	.26
50	E	.25	.31	.28

* M = Math; S = Science; E = Electricity or Radio

APPENDIX C

FIRST DATA PREPARATION PROGRAM



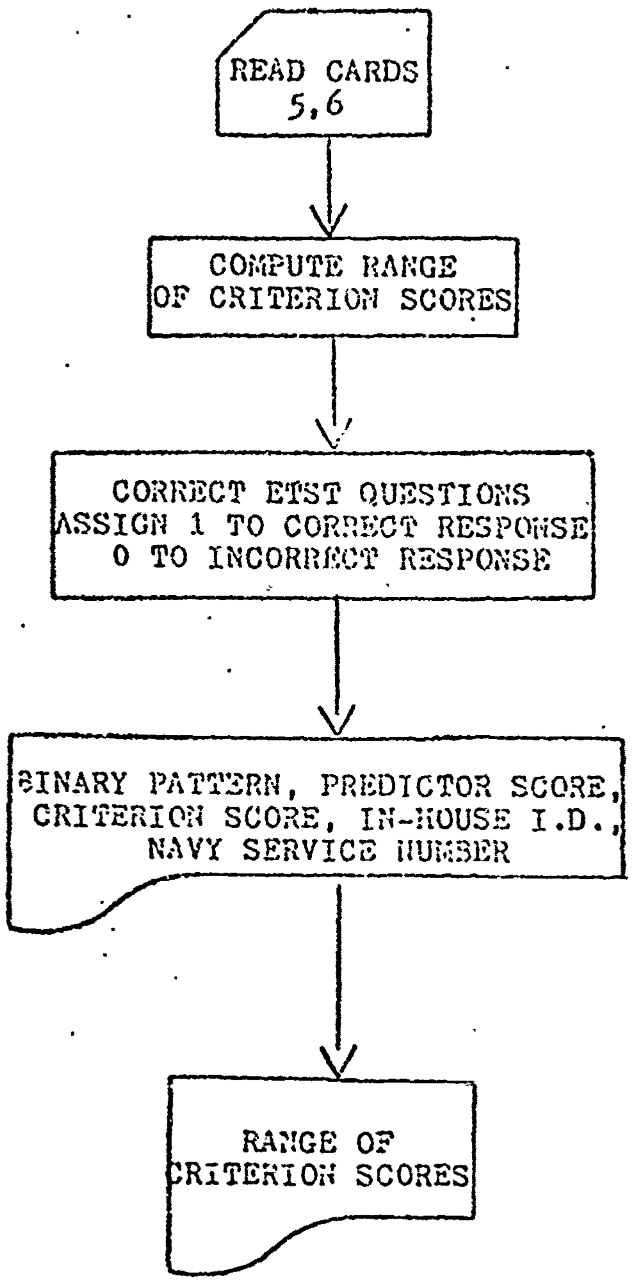
APPENDIX D

Listing of First Data Preparation Program

```
C
C
C   THIS PROGRAM EDITS RAW DATA FOR USE IN ETST STUDY
C
        INTEGER*2 DASH,ZERO,BLANK,IW,IC3,IC4,IC5
        DIMENSION IW(80)
        DATA DASH/'- '/,ZERO/'0 '/,BLANK/'  '/,IC3/'3 '/,IC4/'
       1IC5/'5 '/,IC6/'6 '/,STAR/'* '/,IC1/'1 '/,IC2/'2 '/
        K=1
C
C
C   CHECK CARD NUMBER
 10     READ(4,400,END=500) IW
        IF(IW(8).EQ.IC1) GO TO 12
        IF(IW(8).EQ.IC2) GO TO 12
        IF(IW(8).EQ.IC3) GO TO 10
        IF(IW(8).EQ.IC4) GO TO 10
        IF(IW(8).EQ.IC5) GO TO 12
        IF(IW(8).EQ.IC6) GO TO 12
 400    FORMAT(80A1)
C
C
C   ZEROIZE STARS, BLANKS, DASHES
 12     DO 20 I=1,80
        IF(IW(I).EQ.STAR) IW(I)=ZERO
        IF(IW(I).EQ.BLANK) IW(I)=ZERO
        IF(IW(I).EQ.DASH) IW(I)=ZERO
 20     CONTINUE
        WRITE(8,300) IW
        WRITE(6,401) IW
 300    FORMAT(80A1)
 401    FORMAT(1X,80A1)
        GO TO 10
 500    IF(K.GE.2) GO TO 99
        K=K+1
        GO TO 10
 99     STOP
        END
//GO.FT06F001 DD SPACE=(CYL,(5,5),RLSE)
//GO.FT04F001  DD  UNIT=2400,VOL=SER=NPS416,DISP=(OLD,PASS),
//  DCB=(RECFM=FB,LRECL=80,BLKSIZE=4800),LABEL=(1,NL,,IN),
//    DSN=&F1
//GO.FT04F002  DD  UNIT=2400,VOL=SER=NPS416,DISP=(OLD,PASS),
//  DCB=(RECFM=FB,LRECL=80,BLKSIZE=4800),LABEL=(2,NL,,IN),
//    DSN=&F2
//GO.FT08F001 DD DISP=(NEW,KEEP),UNIT=2321,VOL=SER=CEL001,
//    LABEL=EXPDT=73180,SPACE=(TRK,(571)),DSNAME=SC575.KPW2,
//    DCB=(RECFM=FB,BLKSIZE=2000,LRECL=80)
```

APPENDIX E

SECOND DATA PREPARATION PROGRAM



```
C                 APPENDIX F
C              Listing of Second Data Prepation Program
C
C   THIS PROGRAM EDITS DATA FROM THE ETST TEST
C     A(J)=PREDICTOR,C(J)=CRITERION,D(J)=SERV.NO.,
C
      IMPLICIT INTEGER*4(A-Z)
      DIMENSION A(2500),C(2500),D(2500),W(7)
      DATA ISAMP,NREAD,NWRITE,NPUNCH,IHI,ILO/2400,8,6,7,
     156,56/
      DO 100 J=1,ISAMP
      IF(J.EQ.2398) GO TO 50
 10   READ(NREAD,1,END=50) B,D(J),KDNUM,(W(I),I=1,7)
 1    FORMAT(A1,I6,I1,T11,I1,T19,I1,T21,I1,T30,I1,T48,I1,
     1T49,I1,T58,I1)
C
C   THIS PHASE CHECKS FOR THE PRESENCE OF CARD NUMBERS
C   FIVE AND SIX
      IF(KDNUM.EQ.5) GO TO 3
      GO TO 10
 3    K=1
      READ(NREAD,2) KDNUM,A(J),C(J)
 2    FORMAT(T8,I1,T52,I2,T64,I2)
      IF(KDNUM.EQ.6) GO TO 7
      GO TO 10
 7    K=K+1
      IF(K.NE.2) GO TO 10
C
C   THIS PHASE DETERMINES RANGE OF CRITERION SCORES
      IF(C(J).EQ.0) GO TO 12
      IF(C(J).LT.ILO) ILO=C(J)
      IF(C(J).GT.IHI) IHI=C(J)
C
C   THIS PHASE DETERMINES CORRECT/INCORRECT RESPONSES
C   OF SELECTED ETST ITEMS NOS. 3,11,13,22,40,41, AND 50
 12   IF(W(1).NE.5) W(1)=0
      IF(W(2).NE.5) W(2)=0
      IF(W(3).NE.5) W(3)=0
      IF(W(4).NE.2) W(4)=0
      IF(W(5).NE.3) W(5)=0
      IF(W(6).NE.2) W(6)=0
      IF(W(7).NE.3) W(7)=0
      DO 20 I=1,7
      IF(W(I).EQ.0) GO TO 20
      W(I)=1
 20   CONTINUE
C
C   OUTPUT INFO ONTO CARDS, DATA CELL, PAPER
C   'J' IS USED AS INHOUSE ID
      WRITE(NWRITE,30) (W(I),I=1,7),C(J),A(J),J,B,D(J)
 30   FORMAT(4(1X,7I1,I2,I2,I4,T20,A1,I6,5X))
      WRITE(NPUNCH,40) (W(I),I=1,7),C(J),A(J),J,B,D(J)
      WRITE(4,40) (W(I),I=1,7),C(J),A(J),J,B,D(J)
 40   FORMAT(7I1,I2,I2,I4,T20,A1,I6)
 100  CONTINUE
 50   WRITE(6,25) IHI,ILO
 25   FORMAT(' IHI EQUALS',I2,/' ILO EQUALS',I2,/)
      STOP
      END
//GO.FT06F001 DD SPACE=(CYL,(5,5),RLSE)
//GO.FT07F001 DD SYSOUT=B
//GO.FT08F001 DD DSN=S0575.KPW2,UNIT=2321,VOL=SER=CEL001,
//    DCB=(RECFM=FB,BLKSIZE=2000,LRECL=80),DISP=(OLD,KEEP)
//GO.FT04F001 DD DISP=(NEW,KEEP),UNIT=2321,VOLUME=SER=CEL001
//    LABEL=EXPDT=73180,SPACE=(TRK,(571)),DSNAME=S0575.KPW3,
//    DCB=(RECFM=FB,BLKSIZE=2000,LRECL=80)
```

```
C                APPENDIX G
C                   Listing of Validation Program
C
C
C      THIS PROGRAM WORKS ON ODD NUMBERED QUESTIONS FROM THE
C      ETST EXAM. THE MULTIPLE CORRELATION COEFFICIENT IS
C      CALCULATED AS WELL AS THE CORRELATION COEFFICIENT
C      BETWEEN PATTERN AND T OTAL CORRECT.
C
C
       INTEGER*4 A,C,D,E,G,H,P
       REAL*8 C1,C2,A1,A2,V,W,X,R1,R2,R3,R4,R5,Q,Z1,Z2,Z3,Z,
      1R1STAR,AA,BB
       DIMENSION A(1200),B(1200),C(1200),D(1200),E(1200),
      1F(128,47),G(128),H(128),P(7,1200),S(128),X(1200)
       DATA N1,N2,N3,N4/1182,7,47,128/
       L=0
C
C
C      READ IN DATA
C
       DO 13 J=1,N1
       READ(9,9)(P(I,J),I=1,N2),C(J),A(J),D(J)
  9    FORMAT(7I1,I2,I2,I4)
C
C
C      IDUM IS A DUMMY VARIABLE CONTROLLING THE READING OF
C      EITHER EVEN OR ODD DATA.
C
       READ(9,2) IDUM
  2    FORMAT(I1)
 13    CONTINUE
C
C
C      COUNT TOTAL ONES FOR EACH SUBJECT
C
  5    DO 15 J=1,N1
       E(J)=0
       DO 12 I=1,N2
       E(J)=P(I,J)+E(J)
 12    CONTINUE
 15    CONTINUE
       IA1=0
       IA2=0
       IV=0
       DO 8 J=1,N1
C
C
C      IA1, IA2, IV ARE VARIABLES TO BE USED IN THE CALCU-
C      LATION OF R(TOTAL ONES) LATER IN THE PROGRAM.
C
       IA1=E(J)+IA1
       IA2=E(J)*E(J)+IA2
       IV=C(J)*E(J)+IV
  8    CONTINUE
C
C
C      OUTPUT VALUES FOR IA1, IA2 TO BE USED IN THE
C      COMPUTATION OF TEST-RETEST CORRELATION COEFFICIENT.
C
       WRITE(6,999) IA1,IA2
 999   FORMAT(T20,'IA1=',I8,//,T20,'IA2=',I8)
C
C
C      DETERMINE THE JOINT FREQUENCY DISTRIBUTION OF PATTERN
C      AND CRITERION SCORES (THE SECOND I LOOP CONVERTS
C      BINARY NUMBER PATTERNS TO DECIMAL EQUIVALENTS
C      TO SERVE AS ROW ADDRESSES.
C
       DO 14 I=1,N4
       DO 17 J=1,N3
       F(I,J)=0
```

```
17    CONTINUE
14    CONTINUE
      DO 18 J=1,N1
      M=1
      K=N4
      DO 19 I=1,N2
      K=K/2
      M=K*P(I,J)+M
19    CONTINUE
      N=C(J)-29
      F(M,N)=F(M,N)+1
      B(J)=M
18    CONTINUE
C
C
C     COMPUTATION OF PATTERN SCORES
C
      DO 20 I=1,N4
      S1=0
      S2=0
      DO 21 J=1,N3
      S2=F(I,J)+S2
      S1=(J+29)*F(I,J)+S1
21    CONTINUE
      IF(S2.EQ.0) GO TO 10
      S(I)=S1/S2
      GO TO 20
10    S(I)=-1
20    CONTINUE
      WRITE(7,25)(S(I),I=1,N4)
25    FORMAT(10F7.4)
C
C
C     ASSIGNMENT OF PATTERN SCORES TO SUBJECTS
C
      DO 31 J=1,N1
      K=B(J)
      X(J)=S(K)
31    CONTINUE
C
C
C
C     COMPUTATION OF CORRELATIONS
C
      A1=0.D0
      A2=0.D0
      C1=0.D0
      C2=0.D0
      X2=0.D0
      X1=0.D0
      V=0.D0
      W=0.D0
      UU=0.
      DO 41 J=1,N1
      C1=C(J)+C1
      C2=C(J)*C(J)+C2
      A1=A(J)+A1
      A2=A(J)*A(J)+A2
      X1=X(J)+X1
      X2=X(J)*X(J)+X2
      V=C(J)*A(J)+V
      W=C(J)*X(J)+W
      UU=E(J)*X(J)+UU
41    CONTINUE
      R3=(N1*C2)-(C1*C1)
      R2=(N1*X2)-(X1*X1)
      R5=(N1*W)-(C1*X1)
      Q=(R2*R3)**0.5
      R2=R5/Q
C
C
C     FIRST TIME THROUGH PROGRAM R1 IS THE CORRELATION
```

```
C     COEFFICIENT FOR PATTERN SCORE VS. CRITERION. SECOND
C     TIME THROUGH R1 IS CORRELATION COEFFICIENT FOR TOTAL
C     ONES VS. CRITERION.
C
 30   R1=(N1*A2)-(A1*A1)
      R4=(N1*V)-(C1*A1)
      Q=(R1*R3)**0.5
      R1=R4/Q
      IF(L.EQ.1) R1STAR=R1
C
C
C     COMPUTATION OF TEST STATISTIC FOR R DIFFERENCE
C
      Z1=(1+R1)/(1-R1)
      Z1=DLOG(Z1)/2
      IF(L.EQ.1) GO TO 40
      Z2=(1+R2)/(1-R2)
      Z2=DLOG(Z2)/2
      Z3=2./(N1-3.)
      Z3=(Z3)**0.5
 40   Z=(Z2-Z1)/Z3
      IF (L.EQ.1) GO TO 90
C
C
C     CONSTRUCTION OF RESPONSE PATTERNS
C
      G(1)=2
      H(1)=0
      G(2)=1
      H(2)=1
      K=1
      N=1
 50   N=2*N
      IF(N.GE.N4) GO TO 60
      K=10*K
      DO 51 I=1,N
      G(N+I)=G(I)+K
      H(N+I)=H(I)+1
      G(I)=G(I)+2*K
 51   CONTINUE
      GO TO 50
C
C
C     ORDERING OF RESPONSE PATTERNS
C
 60   N=N4-1
 70   K=0
      DO 80 I=1,N
      V=G(I)
      W=H(I)
      IF (S(I+1).GE.S(I)) GO TO 80
      U=S(I)
      V=G(I)
      W=H(I)
      S(I)=S(I+1)
      G(I)=G(I+1)
      H(I)=H(I+1)
      S(I+1)=U
      G(I+1)=V
      H(I+1)=W
      K=1
 80   CONTINUE
      IF (K.EQ.1) GO TO 70
C
C
C     PRINT OUT
C
      NUM=1
      NUM1=32
 99   WRITE(6,100)(G(I),H(I),S(I),I=NUM,NUM1)
 100  FORMAT('1',6(/),T60,'ETST EXAM',2(/),T45,'+',
     &38('-'),'+',/,T45,'|',1X,'PATTERN',
```

```
C
C
C      THE VARIABLE R7 IS THE CORRELATION COEFFICIENT BETWEEN
C      PATTERN SCORES AND TOTAL CORRECT (ONES).
C
       R7=N1*UU-IA1*X1
       WRITE(6,33) R7,UU
 33    FORMAT(' R7=',F18.4,'UU=',F18.4)
 37    FORMAT(' R7=',F18.4,'UU=',F18.4)
       R1=(N1*A2)-(A1*A1)
       R8=(N1*X2)-(X1*X1)
       Q=(R1*R8)**.5
       R7=R7/Q
       WRITE(6,213) R7
 213   FORMAT('0','R(PATTERN SCORE/TOTAL ONES) EQUALS',F6.3)
C
C
C      RMUL IS THE MULTIPLE CORRELATION COEFFICIENT TO BE
C      USED IN THE DETERMINATION OF 'F'.
C
       RMUL=((R2**2)+(R1STAR**2)-2*(R2*R1STAR*R7))/(1-R7**2)
       RMUL=RMUL**.5
       FF=((RMUL**2)-(R1STAR**2))*(N1-3)/(1-(RMUL**2))
       WRITE(6,417) RMUL,FF
 417   FORMAT('0','R(MULT. CORREL. COEF.) EQUALS',4X,F6.4,//,
      1' FF EQUALS',F8.4)
C
C
C      THIS PORTION OF THE PROGRAM IS USED IN THE DETERMINA-
C      TION OF A FREQUENCY DISTRIBUTIONF I.E. PATTERN
C      VS. NUMBER OF PEOPLE WITH THAT PATTERN
C
C
       DO 350 I=1,128
       WRITE(6,357) G(I),S(I)
 357   FORMAT(T20,'A PATTERN OF:',2X,I7,2X,'AND PATTERN SCORE
      13X,F8.4,//)
       KOUNT=0
       DO 355 J=1,N1
       IF(S(I).EQ.X(J)) GO TO 359
       GO TO 355
 359   KOUNT=KOUNT+1
       WRITE(6,352) D(J)
 352   FORMAT(T15,I4)
 355   CONTINUE
       WRITE(6,351) KOUNT
 351   FORMAT(' TOTAL PEOPLE HAVING THIS SCORE:',I3,//)
 350   CONTINUE
       STOP
       END
//GO.FT06F001 DD SPACE=(CYL,(5,1)),SYSOUT=D
//GO.FT07F001 DD SYSOUT=B
//GO.FT09F001 DD DSN=SJ575.KPW3,UNIT=2321,VOL=SER=CEL001,
//    DCB=(RECFM=FB,BLKSIZE=2000,LRECL=80),DISP=(OLD,KEEP)
```

APPENDIX H

Output I - Pattern Information

ETST EXAM

PATTERN	TOTAL ONES	PATTERN SCORE
2222112	2	-1.0000
2222111	3	-1.0000
2212121	3	-1.0000
2212111	4	-1.0000
2122121	3	-1.0000
2122112	3	-1.0000
2122111	4	-1.0000
2121122	3	-1.0000
2112211	4	-1.0000
2112112	4	-1.0000
1212111	5	-1.0000
1122121	4	-1.0000
1122112	4	-1.0000
1122111	5	-1.0000
2212211	3	48.5000
2222211	2	49.0000
2222222	0	49.6071
1222222	1	51.3182
2222121	2	52.0000
2122211	3	52.0000
2221222	1	52.5238
2222212	1	52.5833
1222121	3	53.5000
2222221	1	53.6667
2122222	1	53.8000
2121211	4	54.0000
2222122	1	54.1667
2221212	2	54.3000
2212122	2	54.5000
2212222	1	54.5500
1212222	2	54.7500
1222212	2	54.8889

NOTE 1: IN PATTERNS, 2'SREPRESENT 0'S
NOTE 2: A PATTERN SCORE OF -1 INDICATES A PATTERN NO ONE HAS

APPENDIX H

Output I - Pattern Information

ETST EXAM

PATTERN	TOTAL ONES	PATTERN SCORE
2221221	2	56.0000
2112111	5	56.0000
1222122	2	56.3333
2122221	2	56.5000
2122212	2	56.5000
1222112	3	56.5000
1212122	3	56.6000
2121212	3	56.8750
22122[illegible]2	2	57.2500
1122222	2	57.3333
122122[illegible]	2	57.3913
112222[illegible]	3	57.6000
2211222	2	57.7308
2221121	3	58.0000
2121222	2	58.0000
2112212	3	58.0000
2211212	3	58.2941
1212212	3	58.3077
1221221	3	58.3333
2221211	3	58.5000
2211122	3	58.7143
1212221	3	58.8750
2211221	3	58.9091
2221122	2	59.0000
2211211	4	59.0000
1222111	4	59.0000
1221212	3	59.2222
1221211	4	59.2500
1222221	2	59.5000
2121112	4	59.6667
2112222	2	59.7143
1211222	3	60.0682

NOTE 1: IN PATTERNS, 2'SREPRESENT 0'S
NOTE 2: A PATTERN SCORE OF -1 INDICATES A PATTERN NO ONE HAS

(Continued)

APPENDIX H

Output I - Pattern Information

ETST EXAM

PATTERN	TOTAL ONES	PATTERN SCORE
2111222	3	60.7333
1221122	3	60.7500
2121221	3	61.0000
1121222	3	61.0000
1112122	4	61.2500
2212221	2	61.6667
1212211	4	61.6667
2221112	3	62.0000
2212112	3	62.0000
2122122	2	62.0000
2111212	4	62.2222
1211221	4	62.2308
2112121	4	62.5000
1212112	4	62.5000
1122212	3	62.5714
1112222	3	62.8621
2112221	3	63.0000
1122212	4	63.2609
1211212	4	63.2857
1122122	3	63.5000
1121212	4	63.5625
1211122	4	63.6000
1112121	5	63.7500
2121121	4	64.0000
2112122	3	64.0000
1211211	5	64.0000
1122211	4	64.2500
1111222	4	64.4000
2111122	4	64.6000
1121122	4	64.8000
2211121	4	65.0000
2111221	4	65.0000

NOTE 1: IN PATTERNS, 2'SREPRESENT 0'S
NOTE 2: A PATTERN SCORE OF -1 INDICATES A PATTERN NO ONE HAS

(Continued)

APPENDIX H

Output I - Pattern Information

ETST EXAM

PATTERN	TOTAL ONES	PATTERN SCORE
2211112	4	65.2000
1221112	4	65.2000
1211112	5	65.3000
1121221	4	65.3000
1112211	5	65.5000
1111212	5	65.6097
1112112	5	65.7500
2111121	5	65.7778
1112221	4	65.8571
2111112	5	66.0000
1222211	3	66.0000
1121112	5	66.3333
2121111	5	66.5000
2111211	5	66.7500
1111221	5	66.7667
1111122	5	67.7273
2221111	4	68.0000
1221111	5	68.3333
1211121	5	68.5000
1121211	5	68.5000
1111211	6	68.5000
1111112	6	68.7500
1212121	4	69.5000
1121121	5	69.6667
2211111	5	69.8333
2111111	6	70.0000
1112111	6	70.5000
1211111	6	70.8000
1221121	4	71.0000
1111121	6	71.2954
1111111	7	73.2857
1121111	6	73.6667

NOTE 1: IN PATTERNS, 2'SREPRESENT 0'S
NOTE 2: A PATTERN SCORE OF -1 INDICATES A PATTERN NO ONE HAS

(Continued)

APPENDIX I

Output II - Subject Information

ETST EXAM

IDENT	PREDICTOR	CRITERION	PATTERN SCORE	TOTAL ONES
1	66	76	68.7500	6
3	59	53	54.7500	2
5	57	54	54.7500	2
7	73	73	71.2954	6
9	56	60	58.9091	3
11	71	70	66.0000	5
13	63	64	64.4000	4
15	59	57	54.5500	1
17	64	56	57.3913	2
19	64	54	49.6071	0
21	46	58	54.7500	2
23	56	56	58.8750	3
25	56	60	65.6097	5
27	55	54	58.2941	3
29	60	68	68.7500	6
31	49	57	54.7500	2
33	55	62	60.0682	3
35	72	76	73.2857	7
37	68	71	68.7500	6
39	66	68	65.8571	4
41	73	71	70.0000	6
43	65	60	64.4000	4
45	59	59	61.0000	3
47	63	76	73.6667	6
49	65	64	62.5000	4
51	54	38	51.3182	1
53	66	64	62.8621	3
55	58	62	57.2500	2
57	51	59	57.2500	2
59	61	64	65.2000	4
61	62	68	65.3000	4
63	63	67	70.0000	6
65	60	62	56.0000	2
67	66	70	68.5000	5
69	68	69	63.6000	4
71	60	68	68.5000	6
73	62	60	54.5500	1
75	58	60	56.8750	3
77	65	59	54.7500	2
79	58	58	61.0000	3
81	62	57	56.0000	2
83	63	71	69.5000	4
85	59	58	57.7308	2
87	70	76	73.2857	7
89	59	70	65.7778	5
91	51	61	60.0682	3
93	51	49	52.5238	1
95	45	60	57.6000	3
97	66	68	68.5000	5
99	71	65	68.7500	6

```
C       APPENDIX J
C                          Cross-Validation Listing
C
C       CROSS VALIDATION
C
        INTEGER*4 A,C,D,E,G,H,P
        REAL*8 C1,C2,A1,A2,V,W,X,R1,R2,R3,R4,R5,Q,Z1,Z2,Z3,Z,
       1AA,BB
        DIMENSION A(1200),B(1200),C(1200),D(1200),E(1200),
       1G(128),H(128),P(7,1200),S(128),X(1200)
C
C       NOTE: PARAMETERS OF DATA CARD
C
        CATA N1,N2,N3,N4/1182,7,47,128/
        L=0
C
C
C       READ IN CATA
C
        CO 13 J=1,N1
C
C
C       THIS CROSS VALIDATION PROGRAM READS DATA FROM THE
C       ETST EXAM
C
C
C
C
C       IDUM IS A DUMMY VARIABLE CONTROLLING THE READING OF
C       EITHER EVEN OR CLD CATA.
C
        READ(4,2) IDUM
 2      FORMAT(I1)
        READ(4,9) (P(I,J),I=1,N2),C(J),A(J),D(J)
 9      FORMAT(7I1,I2,I2,I4)
 13     CONTINUE
C
C
C       READ REGRESSED MEAN AND WEIGHT COMPUTED FROM THE
C       MAIN PROGRAM.
C
        READ(5,3) AA,BB
 3      FORMAT(F6.3,F6.3)
C
C
C       READ PATTERN SCCRES CALCULATED FROM MAIN PROGRAM
C
        READ(5,10)(S(I),I=1,N4)
 10     FORMAT(10F7.4)
C
C
C       COUNT TOTAL CORRECT FCR EACH SUBJECT
C
        DO 15 J=1,N1
        E(J)=0
        DC 12 I=1,N2
        E(J)=P(I,J)+E(J)
 12     CONTINUE
 15     CONTINUE
        IA1=0
        IA2=0
        IV=0
C
C
C       IA1, IA2, IV ARE VARIABLE TO BE USED IN THE CALCU-
C       LATION OF R(TOTAL CNES) LATER IN THE PROGRAM.
C
        CO 8 J=1,N1
        IA1=E(J)+IA1
        IA2=E(J)*E(J)+IA2
        IV=C(J)*E(J)+IV
 8      CONTINUE
```

```
C
C
C     OUTPUT VALUES FOR IA1, AND IA2 TO BE USED IN THE
C     COMPUTATION OF TEST-RETEST CORRELATION COEFFICIENT.
C
      WRITE(6,999) IA1,IA2
  999 FORMAT(T20,'IA1=',I8,//,T20,'IA2=',I8)
C
C
C     CALCULATE DECIMAL ECUIVALENT OF BINARY PATTERNS
C     THE B(J) ARRAY HOLDS DECIMAL EQUIVALENT OF EACH
C     SUBJECT'S BINARY PATTERN.
C
      DO 18 J=1,N1
      M=1
      K=N4
      DO 19 I =1,N2
      K=K/2
      M=K*P(I,J)+M
   19 CONTINUE
      B(J)=M
   18 CONTINUE
C
C     ASSIGNMENT OF PATTERN SCORES TO SUBJECTS
      DO 31 J=1,N1
      K=B(J)
      X(J)=S(K)
      IF(X(J).LT.0) X(J)=E(J)*BB+AA
   31 CONTINUE
C
C     COMPUTATION OF CORRELATIONS
      A1=0.D0
      A2=0.D0
      C1=0.D0
      X1=0.D0
      X2=0.D0
      W=0.D0
      V=0.D0
      UU=0.
      C2=0.D0
      DO 41 J=1,N1
      C1=C(J)+C1
      C2=C(J)*C(J)+C2
      A1=A(J)+A1
      A2=A(J)*A(J)+A2
      X1=X(J)+X1
      X2=X(J)*X(J)+X2
      V=C(J)*A(J)+V
      W=C(J)*X(J)+W
      UU=E(J)*X(J)+UU
   41 CONTINUE
      R3=(N1*C2)-(C1*C1)
      R2=(N1*X2)-(X1*X1)
      R5=(N1*W)-(C1*X1)
      Q=(R2*R3)**0.5
      R2=R5/Q
C
C
C     FIRST TIME THROUGH PROGRAM R1 IS THE CORRELATION
C     COEFFICIENT FOR PATTERN SCORE VS. CRITERION. SECOND
C     TIME THROUGH R1 IS CORRELATION COEFFICIENT FOR TOTAL
C     CORRECT VS. CRITERION.
C
   30 R1=(N1*A2)-(A1*A1)
      R4=(N1*V)-(C1*A1)
      Q=(R1*R3)**0.5
      R1=R4/Q
      IF(L.EQ.1) R1STAR=R1
C
C
C     COMPUTATION OF TEST STATISTIC FOR R DIFFERENCE
C
```

```
      Z1=(1+R1)/(1-R1)
      Z1=DLOG(Z1)/2
      IF(L.EQ.1) GO TO 40
      Z2=(1+R2)/(1-R2)
      Z2=DLOG(Z2)/2
      Z3=2./(N1-3.)
      Z3=(Z3)**0.5
 40   Z=(Z2-Z1)/Z3
      IF (L.EQ.1) GO TO 90
C
C
C     PRINT OUT
C
      NUM2=1
      NUM3=50
 199  WRITE(6,200)(D(J),A(J),C(J),X(J),E(J),J=NUM2,NUM3)
 200  FORMAT('1',4(/),T60,'ETST',T67,'EXAM',2(/),T34,'+',
     160('-'),'+',/,T34,'|',1X,'IDENT',1X,'|',1X,
     2' PREDICTOR',1X,'|',1X,'CRITERION',1X,'|',
     3' PATTERN SCORE',1X,'|',1X,'TOTAL ONES','|',/,T33,
     4' |',T95,'|',/'+',T35,60('-'),/,10(5(T34,'|',I5,
     52X,'|',T49,I2,T55,'|',T61,I2,T66,'|',T71,F8.4,
     6T82,'|',T89,I1,T95,'|',/),T34,'|',T95,'|',/'+',
     7T35,60('-'),/))
C
C
C     THE NEXT TWO IF STATEMENTS CONTROL THE NUMBER
C     AND LENGTH OF THE LAST TABLE
C
C
C
C     THE FIRST 'IF' STATEMENT: NUMBER INSIDE PAREN
C     SHOULD BE ONE MULTIPLE OF '5' HIGHER THAN N1; E.G. IF
C     N1=627, NUMBER INSIDE PAREN SHOULD BE 630; IF N1=986,
C     NUMBER INSIDE PAREN SHOULD BE 990.
C
      IF(NUM3.EQ.1190) GO TO 221
      NUM2=NUM2+50
      NUM3=NUM3+50
C
C
C     SECOND 'IF' STATEMENT: NUMBER INSIDE PAREN MUST BE
C     ONE MULTIPLE OF 50 +1 LOWER THAN N1; E.G., IF N1=1286,
C     NUMBER INSIDE PAREN SHOULD BE 1251; IF N1=126,
C     NUMBER INSIDE PAREN SHOULD BE 101.
C
      IF(NUM3.LT.1151) GO TO 199
      NUM2=1151
      NUM3=1190
      GO TO 199
 221  A1=IA1
      A2=IA2
      V=IV
  209  WRITE(6,210) R2,R1,Z
 210  FORMAT('1','CORRELATION AND TESTS'//' ',
     1' R(PATTERN) EQUALS',F15.7,/,
     2'R(PREDICTOR) EQUALS',F15.7,/,
     3' Z EQUALS',F15.7/)
      L=1
      GO TO 30
 90   WRITE(6,212) R1,Z
 212  FORMAT('0','R(TOTAL CORRECT) EQUALS',F15.7/
     1' Z EQUALS',F15.7/)
C
C
C     THE VARIABLE R7 IS THE CORRELATION COEFFICIENT
C     BETWEEN PATTERN SCORES AND TOTAL CORRECT (ONES)
C
      R7=N1*UU-IA1*X1
      WRITE(6,37) R7,UU
 37   FORMAT(' R7=',F18.4,'UU=',F18.4)
      R1=(N1*A2)-(A1*A1)
```

```
      R8=(N1*X2)-(X1*X1)
      Q=(R1*R8)**.5
      R7=R7/Q
      WRITE(6,213) R7
 213  FORMAT('0','R(PATTERN SCORE/TOTAL ONES) EQUALS',F6.3)
C
C
C     RMUL IS THE MULTIPLE CORRELATION COEFFICIENT
C     TO BE USED IN THE DETERMINATION OF 'F'.
C
C
      RMUL=((R2**2)+(R1STAR**2)-2*(R2*R1STAR*R7))/(1-R7**2)
      RMUL=RMUL**.5
      FF=((RMUL**2)-(R1STAR**2))*(N1-3)/(1-(RMUL**2))
      WRITE(6,417) RMUL,FF
 417  FORMAT('0','R(MULT. CORREL. COEF.) EQUALS',4X,F6.4,//,
     1' FF EQUALS',F8.4)
      STOP
      END
//GO.FTC6F001 DD SPACE=(CYL,(5,1))
//GO.FT07F001 DD SYSOUT=B
//GO.FT04F001 DD DSN=S0575.KPW3,UNIT=2321,VOL=SER=CEL001,
//     DCB=(RECFM=FB,BLKSIZE=2000,LRECL=80),DISP=(OLD,KEEP)
//GO.SYSIN DD *
```

APPENDIX K

Output III - Cross-Validation
(First 50 Subjects)

IDENT	PREDICTOR (ETST)	CRITERION (EXAM)	PATTERN SCORE	TOTAL ONES
2	58	62	51.3182	1
4	72	76	71.2954	6
6	65	67	58.5000	3
8	59	52	52.5238	1
10	62	61	62.2308	4
12	71	76	73.2857	7
14	66	67	64.4000	4
16	63	62	65.3000	5
18	48	36	64.2500	4
20	50	52	52.5833	1
22	63	66	66.3333	5
24	61	53	54.5500	1
26	50	56	57.7308	2
28	59	65	54.7500	2
30	62	64	64.4000	4
32	61	58	54.7500	2
34	71	68	65.6097	5
36	65	62	62.8621	3
38	57	58	59.7143	2
40	66	62	57.7308	2
42	65	58	65.8571	4
44	61	56	52.5833	1
46	68	66	69.6667	5
48	70	75	73.2857	7
50	67	59	52.5238	1
52	62	61	64.8000	4
54	68	68	65.6097	5
56	66	65	61.0000	3
58	61	66	71.2954	6
60	59	54	60.7333	3
62	54	55	62.8621	3
64	55	52	62.8621	3
66	51	58	60.7333	3
68	56	51	49.6071	0
70	62	57	54.3000	2
72	60	61	62.2308	4
74	73	67	68.7500	6
76	65	74	73.2857	7
78	52	51	49.0000	2
80	63	74	66.7667	5
82	66	63	54.0000	4
84	70	72	67.7273	5
86	63	64	64.4000	4
88	55	51	54.5500	1
90	67	69	67.7273	5
92	70	71	68.7500	6
94	67	76	67.7273	5
96	53	64	65.0000	4
98	60	62	57.3913	2
100	72	62	67.7273	5

APPENDIX L

GLOSSARY OF COMPUTER VARIABLES USED IN THESE PROGRAMS

A(J) - jth subject's GCT score used as a predictor

A1 - sum of predictors

A2 - sum of squares of predictors

B(J) - jth subject's decimal value of his binary score

C(J) - jth subject's final school grade used as the criterion

C1 - sum of the criterion scores

C2 - sum of squares of criterion score

D(J) - jth subject's identification number

E(J) - jth subject's total correct

F(,) - joint frequency distribution

G( ) binary pattern (2 replaced O in output)

H( ) total correct in a binary pattern

IA1 - sum of total correct (total ones)

IA2 - sum of square of total correct (total ones)

IHI
ILO - used in calculating range of criterion scores

IV - sum of C(J)*E(J)

IW( )- a column on a subject's record card

KDNUM - card number

M - column in 'F matrix'

Glossary of Computer Variables Used in These Programs
(Continued)

N - row in 'F matrix'

N1 - sample size

N2 - number of elements in the binary pattern

N3 - range of criterion scores

N4 - 2**N2; number of combinations of patterns of 1/0 with N2 questions

P(,) - jth subject's pattern of ones/zeros

R1 - correlation coefficient between criterion/predictor
2nd time corelation coefficient between criterion/total correct

R2 - correlation coefficient between criterion/pattern

R3-5 - correlation coefficients used in determining R1 and R2

R7 - correlation coefficients between pattern scores and total ones

RMUL - multiple correlation coefficient

S(I) - a pattern score associated with a particular pattern

S1 - weighted sum of people with that pattern (weights being the criterion scores)

S2 - number of people with that pattern

V - sum of product of C(J)*A(J)

W - sum of product of C(J)*X(J)

W(1-7) - an array of questions being used in this study

X(J) - jth subject's pattern score

X1 - sum of pattern scores

X2 - sum of square of pattern score

Glossary of Computer Variables Used in These Programs
(Continued)

Z - test statistic

F - test statistic F distribution

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